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Uncertainties and sustainability concepts in biofuel supply chain management: A review

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A B S T R A C T

Biofuel energy as an alternative and additive form of energy to fossil fuel has gained much attention in recent times. In order to sustain such a vision, a robust supply chain is of extreme importance in helping to deliver competitive biofuel to the end user markets. In this paper, firstly, an introduction of the evolution of biofuels and the general structure of the biofuel supply chain are presented. Secondly, the three types of decision making levels and uncertainties that are inherent within the biofuel supply chain are discussed. Thirdly, important methodologies for modeling uncertainties in the decision making process are provided. Fourthly, sustainability concepts and models that give perspectives to the social, economical and environmental concepts are reviewed. Finally, conclusions and future research based on incorporating uncertainties and sustainability concepts within the biofuel supply chain are drawn and suggested, respectively.

Contents

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1. Introduction

In order to ensure future energy security and sustainability, renewable energy has attracted the attention of researchers in both academia and industry. Biofuel energy is one of the renewable energy that has gained grounds in this regard. The U.S. Environmental Protection Agency (EPA) announced starting ethanol production at 4 billion gallons in 2006, and increasing each year by 700 million gallons. This will reach a level of 7.5 billion gallons in 2012 [1]. These contributions are important in helping to improve the environment by reducing the Green House Gas emission (GHG), and possibly increasing economic activities in most parts of the country [2].

Biofuels include a wide range of fuels which are derived from biomass. The major products cover liquid biofuels and various biogases [3]. Bioethanol is an example of liquid fuels that are used as substitutes as well as additives for transportation fuel. Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes. It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate, can be used as a biofuel or a fertilizer.

Biofuel supply chain consists of a network of producers of the raw material (biomass), biorefineries, storage facilities, blending stations and end users. Many researchers have focused on technologies that transform biomass to biofuel. But in order to deliver a competitive end product to the end user markets, a robust, reliable and sustainable biofuel supply chain is essential [4]. The biofuel supply chain management should provide three main levels of management decisions to ensure the delivery of the finished products from the origin to the destination in an efficient and effective manner. These decisions can be strategic, tactical and operational. Due to the nature of the biofuel supply chain, many uncertainties exist. The uncertainties include, but are not limited to: raw material supply and price uncertainties, finished goods demand and price uncertainties; pre-treatment uncertainties, production and yield uncertainties and transportation uncertainties. In order to achieve optimal performance, the decisions of biofuel supply chain management should incorporate these uncertainties [4]. However, few literature which model uncertainties in biofuel supply chain have been found. Therefore, this review discusses the uncertainties in biofuel supply chain and provides some modeling methodologies. In addition, sustainability issues that are related to economic, social and environmental factors should be considered in the supply chain optimization in order to sustain the health of the biofuel supply chain. Hence, sustainability concepts have been discussed in the paper as well. Some modeling methods are presented to model these issues in biofuel supply chain, which have been found in the literature.

The rest of the paper is organized as follows: Section 2 provides an overview of the biofuel supply chain. Section 3 considers the decision making in biofuel supply chain. Section 4 discusses the uncertainties in the biofuel supply chain management. In Section 5, an outline of the stochastic modeling methods that have been applied in other supply chains are provided. Section 6 identifies the sustainability concepts and provides some sustainability models that can be integrated into the biofuel supply chain. Section 7 finally draws the conclusion and provides future research direction.

2. Background and evolution of biofuel

Biofuels have been in existence for decades. It can be traced to the late 1800s when their major purpose was for cooking, heating and other needs. Due to the changing technology and production for commercialization, a structured market is available for its trading [5]. Biofuels are being used for basic energy needs and as blends or substitutes for the traditional fuel sources, that is, petroleum.

There are currently four generations of biofuel. The raw materials of the first generation biofuels are obtained from food crops. Examples are corn, sugar beets, sugarcane, and any sugar or starch. The technological method used to produce first generation biofuel is called enzymation, or enzyme digestion that releases sugars from starchy materials in the feedstock. According to [6] the first generation biofuel are produced primarily from food crops. The raw materials used usually have higher octane rating, which measure the tendency of the fuel to burn in a particular manner that is suitable for the engine. This has gotten to the stage where increasing measures are being made to address these limitations, by the introduction of the second and third generation biofuels.

Second and third generation biofuels are produced from residues of crop and forest, industrial wastes and non-food energy crops. The raw materials for the second generation include cellulosic materials, switchgrass, waste biomass, wheat stalks, corn stalks, wood, and special energy or biomass crops, e.g. Miscanthus. Second generation biofuels use liquid technology to transform solid biomass to biofuel [7]. This technology mimics the biological digestion of ruminants as they digest the grass they have eaten, which is called enzymatic digestion. Example of the third generation biofuel is algae, which is mostly being developed today. No commercialization production has begun yet since researchers are conducting experiments in identifying mechanisms of the decomposition of the cellulose into sugars. One of the advantages of the second and third generation of biofuels is provision of additive impacts with the usage of raw materials that do not compete with food. This is the main reason why the second and third generation biofuels are preferred since they use raw materials that are readily available, cheap, no competition with food, and reduction in Green House Gas emissions (GHG). This is made clear by [8] indicating that the first-generation biofuels appeared unsustainable because of the potential stress that their production places on food commodities. Also, the high level of content of lignin and cellulose makes it desirable for higher carbon content which makes it more effective and suitable for usage in bioenergy production.

The fourth generation biofuels are currently ongoing and has not generated as much attention as there are still pressing policy and other needs for the first, second and third generations. Numerous organizations and start up are advancing the concept of bio-chemical and thermo-chemical processes that produce drop in fuels like green gasoline, green diesel, and green aviation fuel. This has been the case because there is no formal definition for the term fourth-generation biofuels. While some quarters have referred to it as the biofuels created from processes other than first generation ethanol and biodiesel, second generation cellulosic ethanol, and third generation algae biofuels [9]. Some fourth generation technology pathways include: pyrolysis, gasification, upgrading, solar-to-fuel, and genetic manipulation of organisms to secrete hydrocarbons. Tables 1–3 summarize the similarities, differences, and sustainability concepts of the first, second and third, and fourth generation biofuel.

2.1. General structure of the biofuel supply chain

Fig. 1 shows the general framework of the biofuel supply chain. The major elements in the biofuel supply chain are: (1) farms, (2) storage facilities, (3) biorefinery plants, (4) blending facilities, (5) retail outlets, and (6) transportation. In general, biomass raw materials are transported by trucks from the neighboring farms to the biofuel refinery plant through the farm cooperatives. Cooperatives act as the liaison between the producers and the buyers. Storage facilities are needed between farms and biorefineries. Pretreatment storage is also provided to ensure raw material freshness and

Table 1
Similarities in biofuel generation.

	First generation	Second and third generation	Fourth generation
Energy security	Ensures	Ensures	Ensures
Agricultural and industrial support	Ensures	Ensures	Ensures and other extensions
Reduction of oil imports	Ensures	Ensures	Ensures
Demand and expectation	Ensures	Ensures	Not exactly known- ongoing research
Greenhouse gas emission reduction	Ensures	Ensures	Potential exists

Table 2
Differences in biofuel generation.

	First generation	Second and third generation	Fourth generation
Type of biomass	Uses sugarcane, oil feed, corn and other food substitute as raw material	Uses switchgrass, wood waste and other cellulosic raw material	Uses combination or special process of first and second
Market for trading	Structured markets for trading	Not structured for markets for trading	Not structured for markets for trading
Production technology	Relatively mature section for production	Relatively new and not matured and good for cost reduction	Relatively new and not matured and good for cost reduction
Conversion rate	Lower conversion rate of conversion	Relatively cheaper and sometimes at no cost	Cost could be higher as heating processes are involved
Feedstock availability	Readily available in large quantities in some places, e.g. corn in the USA	Extensive benefits on green house gas emission is limited	Benefits on green house gas emission but not quantified
Cost of building plant and process	This is an expensive option for energy development	Not in commercial quantity, research is still ongoing	Not in commercial quantity, research is still ongoing

Table 3
Sustainability in biofuel generation.

	First generation	Second and third generation	Fourth generation
Environmental benefits	Provided initially breakthrough and increase octane number in gasoline	Close to meeting the claimed environmental benefits	Ongoing
Biodiversity	Might potentially have a negative impact on biodiversity	Lower conversion rate	Not relatively known
Food versus energy competition	Contribute to higher food prices due to competition with food	Lack of technological and research breakthrough	Technological and research still ongoing
Social and environmental impact	Claimed environmental and social benefits	Same	Initial thought, not proven

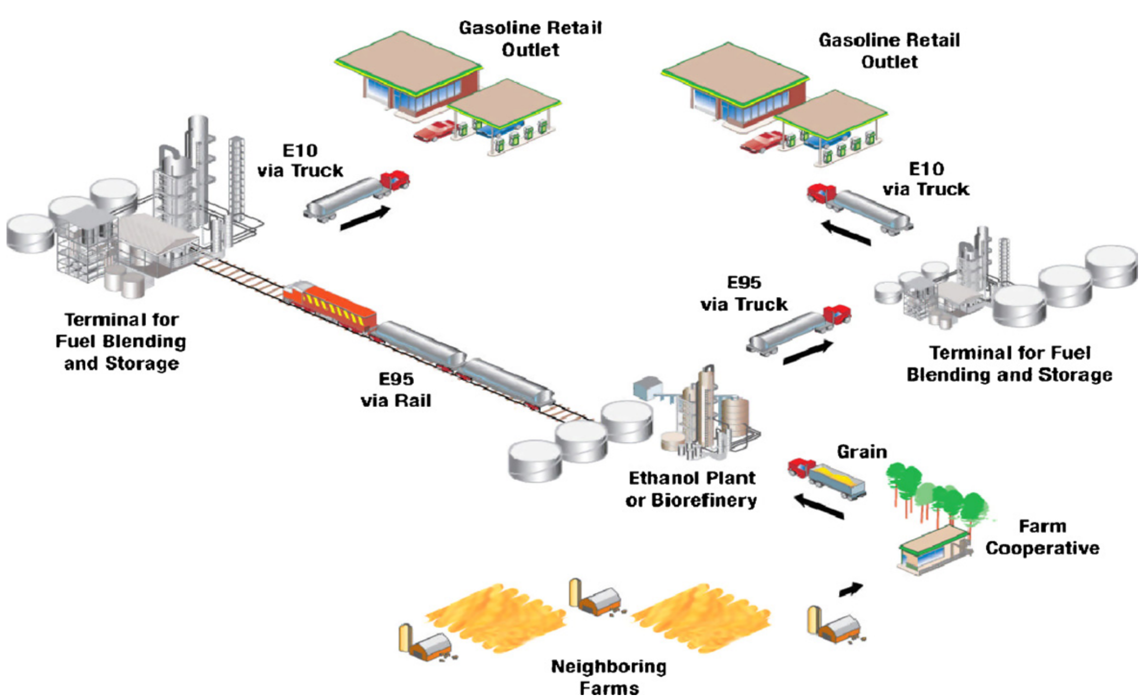

Fig. 1. General framework of the biofuel supply chain.
Source: National Bioenergy Center, National Renewable Energy Laboratory (2005).

increase the conversion rate. In most cases, the feedstock or raw materials are transported from farms directly to the biorefinery. Biomass raw materials are converted into finished goods such as bioethanol, corn oil and distiller's dry grains (DDGS) at the biorefinery. The finished product is transported via trucks to terminals for blending. Blending the ethanol with gasoline is carried out so that the ethanol product will be used for fuel purposes only. This is usually done at the initial stage by denaturing it with other chemicals. The blending of ethanol and gasoline ensures the provision of various grades of ethanol and gasoline combinations such as E85 and E15. The E85 consists of 85% ethanol and 15% of gasoline, while the E15 consists 15% of ethanol and 85% of gasoline. The blended ethanol is subsequently sent to the gasoline retail outlets, where they are sold together with other types of fuel. In the second and third generation of biofuels, terminals for fuel blending have not been given much attention. Some biofuel supply chains have a direct pre-treatment at the refinery or biofuel plants where the raw materials are sent directly as explained previously. A biorefinery plant usually uses various conversion processes to convert the raw materials into the various end products depending on if it is from any type of the generations.

3. Decision making in biofuel supply chain

In general, supply chains consist of a summarized network of suppliers, manufacturers, and end users. Supply chain management is the management of all the activities in the supply chain to ensure the efficiency and effectiveness of the material flow, information flow and cash flow. There are three main decision making processes in supply chain management: strategic, tactical and operational decisions. Strategic decisions are long term decisions which may need revisions after five or more years depending on the business entity. The tactical decisions are medium term decisions usually spanning between six months and one year. They take into account logistical needs, distribution parties or network and inventory planning levels. Usually tactical decisions are made to provide cost benefit due to the constraints of the strategic decisions. Finally, the operational decisions are short term decisions that are made weekly or daily. They help to achieve the tactical decisions outlined. An example is the detailed production scheduling, demand planning and detailed scheduling [10]. The design and management of efficient supply chains in today's competitive environment should focus on optimizing all the decisions to achieve robust and reliable supply chain. Therefore, designing the supply chain of biofuel should focus on optimizing strategic, tactical and operational decisions to reduce system wide total cost or maximize profit.

3.1. *Strategic decisions in biofuel supply chain*

Strategic decisions in biofuel supply chain include, but are not limited to; (1) selection of energy production technologies, (2) network configuration, (3) supply and demand contracts, and (4) ensuring sustainability [11].

Energy production technologies should be selected at the beginning of planning the production of biofuel. The technologies will not be changed in a short-term period. Energy production technologies include; (1) the conversion of waste biomass and organic substrates into energy, which involves a wide range of different types and sources of biomass, (2) conversion options, end user applications and (3) infrastructure requirements [12]. Reasons such as raw material availability, raw material type, cost of building and maintaining the plants, energy and food debate as well as environmental and sustainability issues are all important factors to consider when choosing the type of technology to be used for the biofuel production. This is the reason the technologies cannot be changed very often [13].

Optimal biofuel supply chain network will ensure that the biofuel can be delivered efficiently and effectively to the end-user market [14]. Supply chain network design involves decisions such as sourcing and location of production facilities. One of the most inclusive studies of the design of logistics network is the strategic decision problems that need to be optimized for the long-term efficient operation of a biofuel supply chain [15]. The configuration of Waste to Biomass Supply Chain (WBSC) networks as studied by [16], is comprised of critical decisions that affect the biomass flow and the associated costs. The authors refer to sourcing, procurement of biomass, purchasing, allocation and capacity of intermediate warehouses and location of energy conversion facilities as part of the strategic decisions that are taken. Some key parameters such as the capacity limit of supply nodes and the potential fixed capacity of an existing power plant by [17] are also considered.

Supply and demand contracts involve decisions such as agreed terms of delivery and payment between the producer and the supplier. This might involve standard regulations as practiced in most industries [18]. Some of these measures include governmental R&D programs, tax cuts and exemptions, investment subsidies, feed-in tariffs for renewable electricity and mandatory blending for biofuels quotas. Supply and demand contracts measure the intensity and fusion of having some level of conviction to lure investors. Nonetheless, sufficient biomass supply under stable and reliable conditions help in the sustainability and measure targets for stability. In providing renewable energy policies to a changing market demand for bioenergy [19] suggested a collaborative effort from agricultural, governmental and consumer organizations to fully utilize the varied expertise that each team brings in the overall objective.

Ensuring sustainability are the types of decisions that are made to ensure the entire supply chain is sustainable, and able to support and accomplish its main functions and objective. Sustainability on the other hand ensures that the social, economic and environmental impacts of this supply chain are adequately addressed. A more detailed analysis of this will be considered in Section 6.

3.2. *Tactical decisions in biofuel supply chain*

Tactical decisions are medium term decisions that involve sourcing decisions, production decisions, scheduling, transportation and logistical contracts, and planning process definition [20]. Inventory decisions such as location, quality and quantity of inventory are also considered. Decisions taken at the tactical decision level are planned towards achieving and executing the strategic decisions.

Biomass sourcing decisions are crucial in the Biofuel Supply Chain (BSC) in order to minimize the geographical distance and increase accessibility to the raw material sources among other factors. This ensures that the rather isolated geographical allotment of significant biomass is able to raise the interest of researchers into identifying the available biomass quantities over a region, and subsequently proceeding with the selection of the optimal biomass sources [21].

Production scheduling and inventory decisions in biofuel supply chain are types of the medium term decisions. These decisions are considered as the base of the tactical level in order to streamline the stock of finished products that are produced. Also, the amount of finish goods to be stored based on the raw material availability and overall strategy of the immediate production plan. A presentation of a novel multi-time-stage input–output-based modeling framework for simulating the dynamics of bioenergy supply chains is considered by [22]. One of the key assumptions used in the model is that the production level at the next time-stage of each segment

of the energy supply chain. This adjusts to the output surplus or deficit relative to the targets at the current time period. The objective of the process was to minimize the overall cost of the supply chain by reducing the inventory level and freeing locked up working capital in the warehouse.

Transportation involves the movements of people and goods from one location to the other. Logistics on the other hand considers the management of the flow of the goods, information and other resources in order to meet customer requirements [23]. Transportation and logistics selection or contracting is another important decision in the tactical decision level which seeks to create the link between the various points of processing and delivery. Ref. [24] considered the capability of harvesting, storing and transporting biomass efficiently, at a low cost. This was done by considering the transportation system of a cotton supply chain network and intermodal transportation impact. Assumption basis scheduling and pick up time on the biofuel supply chain respectively are applied. Transportation and logistics usually have a high impact on the efficiency and responsiveness of the entire chain.

3.3. Operational decisions in biofuel supply chain

Operational decisions are short term decisions that ensure the continuous operation of the plants and other processes in the supply chain. These decisions are made daily or weekly and sometimes several times to make sure that products are manufactured, moved and sold in a timely and cost effective manner. Some of the operational level decisions are detailed production scheduling, daily fleet management, and daily or weekly inventory review. The focus here is geared towards achieving the plan or framework set by the tactical supply chain decisions. In the biofuel supply chain, this involves daily activities and planning such as transportation and logistics scheduling, demand forecasting and review to meet the monthly targets. The manufacturing planning for the plants and the detailed production and material requirements planning are usually reviewed at this decision level [25].

Daily production scheduling is used by [26] in optimizing the production of agricultural residues. The authors consider production scheduling as the operational decision, and the raw materials needed and capacity of power plants as some of the parameters in the model. A comparison is provided to investigate the energy production and the agricultural interest in satisfying the objective by [27].

Logistics and fleet management involve important decisions that are made within the operational decision level in the BSC. This ensures that adequate provisions are made in the delivery of the products in a timely fashion. In doing this, one of the important factors to consider is the provision of the necessary technical tools to implement the decisions that are chosen. Ref. [28] examined logistical measurements by surveying geographical areas by using decision support system (DSS) tools. These decision support system tools help to optimize the land area for the usage of the biomass raw material [29]. Operational decisions in the biofuel supply chain impact the material flow, timeliness, efficiency and effectiveness to ensure minimized cost of delivery [30].

4. Uncertainties in biofuel supply chain

Uncertainties will impact the performance of supply chains and should be incorporated in many decision making. The major uncertainties in biofuel supply chain include, but not limited to; (1) raw material supply uncertainty, (2) transportation and logistics uncertainty, (3) production and operation uncertainty, (4) demand and price uncertainty, and (5) other uncertainties.

4.1. Biomass supply uncertainties

Supply uncertainties include raw material yield, type and quality [31]. This raises major concerns in procurement decisions as indicated by [32–36]. Most supply uncertainties in the biofuel supply chain are due to quantity of the biomass yields harvested, quality of the biomass, transportation lead time, and congestion at biomass source [37]. Supply uncertainties can be operational and/or financial. Some of the operational and financial hedging methods are safety stock, multiple suppliers, and forward and future purchase of raw materials respectively. Table 4 outlines some of the supply uncertainties in the biofuel supply chain.

4.2. Transportation and logistics uncertainties

Transportation and logistics uncertainties are the inability to deliver both biomass raw materials and finished products in a timely and cost effective manner. Examples of transportation and logistics uncertainties are delays in fleet scheduling, demand and inventory, transportation cost, lack of coordination, delivery constraints, lack of optimized containers due to low yield supply, cost of warehouse and transportation lanes availability. The provision of an effective movement and delivery of fresh products and services is one of the reasons to consider transportation and logistics uncertainties. Some of the impacts of these types of uncertainties on the supply chain are: increase in freight cost, volatile supply of raw materials and increase in inventory and warehouse cost. Table 5 outlines the uncertainties in transportation and logistics.

4.3. Production and operation uncertainties

Production and operation uncertainties cause the inability to produce the planned quantity of production. Some of these uncertainties are delays in raw materials acquisition, production yields, machine breakdown, lead time constraints and inventory decisions. Decisions made without considering these types of uncertainty will lead to underperformance of the supply chain. For example, firms intend to reduce excess inventories that may lock up working capital. This results in having limited inventory which might cause losses in profit when uncertain disruption of production happens. Table 6 summarizes some of the uncertainties in the production of biofuel supply chain.

4.4. Demand and price uncertainties

Demand uncertainty refers to the unknown or unpredictable variations in the quantity and timing of demand as experienced in a supply chain. Price uncertainty defines the chance or speculation that price of a product might change. Demand and price uncertainties in biofuel supply chain, include, but not limited to, raw material cost (e.g. corn prices), crude oil price, tax subsidies, carbon trading, and governmental policies. Incorporating demand and price uncertainties into the decision making process can reduce expectation for profit generation. Table 7 outlines some of the uncertainties due to demand and price with reasons.

4.5. Other uncertainties

Other types of uncertainties in the biofuel supply chain are sustainability, tax, governmental policies, and regulatory policies. Sustainability uncertainties are meant to bridge the gap between the economic aspects of biofuel, and the social implications. The utilization of the resource without any social and environmental policies is detrimental to the sustainability concept. Table 8 summarizes the uncertainties due to other forms.

Table 4
Supply uncertainties.

Paper	Uncertainty	Reasons
[38]	Supply (quantity)	Shortage of feedstock, technology for harvesting and regulation influx
[39]	Supply (quantity)	Maintaining stable supply of biomass, environmental and economic viability of alternative fuel
[40]	Supply (unavailability of arable land)	Land utilization for other food purposes, paper suggestion eliminating Green House Gas (GHG) emissions if biofuel is used
[41]	Supply (unavailability of lands)	Unreliable supply sources possibly due to the market establishment for corn trading and not for some biomass raw material
[42]	Supply (quantity and quality)	Supply issues due to profit participation rights rather than spot market interactions regarding the supply of raw materials

Table 5
Uncertainties in transportation and logistics.

Paper	Uncertainty	Reasons
[43]	Transportation (delivery)	Unable to locate biofuel plants at an optimized location to ensure electricity and heat usage delivery
[44]	Transportation (intermodal)	To deliver biofuel at the least cost within the supply chain

Table 6
Showing the production and operation uncertainties.

Paper	Uncertainty	Reasons
[45]	Production (supply of raw material)	To be able to stabilize demand variation and therefore simulating raw material delivery to the plant
[46]	Production (inventory balance)	Unable to create an inventory and delivery balance and therefore adopting a plant wide control process

Table 7
Demand and price uncertainties.

Paper	Uncertainty	Reasons
[32]	Demand and price (market volatility)	Evaluating the impact of food security through high energy demand
[33]	Demand and price (market volatility)	Unable to fully assess the impact of tax on energy markets due to volatility
[40]	Price (biomass raw material)	To develop a model pattern for the spatially explicit supply chain
[47]	Price (market size)	To be able to invest in the biofuel supply chain considering the market structure

5. Modeling uncertainties in biofuel supply chain

Due to the nature of the biofuel supply chain, uncertainties exist in all the echelons of the supply chain. In order to eliminate the impact of these uncertainties, we need to incorporate them into the decision making process. Literature does not provide sufficient source on modeling the uncertainties in biofuel supply chain management. Therefore, the following sections discuss the popular methodologies used to incorporate uncertainties in general supply chain management.

5.1. Analytical methods

Analytical methods are one of the methodologies that are used to solve problems with uncertainty. Some of these methodologies are Stochastic Mixed Integer Linear Programs (SMILP), Integer Stochastic Programming (ISP), Stochastic Mixed Integer Non-linear Programs (SMINLP), Markov Decision Process (MDP) and Linear Programs (LP) with Scenario Generation (SG). These methods have seen applications in other supply chains, and might yield significant results if applied in the biofuel supply chain.

The work of [34] developed an improved stochastic method based on the Stochastic Mixed Integer Linear Programming (SMILP) method. It uses an improved solution method, based on the sample average approximation technique. This technique is integrated with the accelerated Benders decomposition for the improvement of the mixed integer linear programming solution phase. This solution method is applicable to problems with large number of scenarios.

In [51], the application of an Integer Stochastic Programming (ISP) method based on a two-stage stochastic capacity planning model is used. Benders decomposition method is applied to solve this problem. The models give some computational results based on serial and parallel implementations of the algorithms that are used. First, an analysis of the wait and see models is presented and then, the results of this analysis are incorporated into the stochastic representation of the model.

Ref. [52] introduced a two-stage stochastic model for supply chain management under uncertainty by applying a Stochastic Mixed Integer Non-linear Method (SMINLP). The decisions are to determine the production topology, plant sizing, product selection, product allocation and vendor selection. The proposed solution algorithms are based on branch and fix algorithm. The branch-and-fix approach is introduced for coordinating the selection of the branching nodes, and the scenario subproblems to be jointly optimized.

A multi-period stochastic planning model using finite scenario generation is developed by [53]. The technique applied is generating scenarios for the mean with given standard deviations as the stochastic terms. The proposed supply chain consists of decisions

Table 8
Other uncertainties in the biofuel supply chain.

Paper	Uncertainty	Reasons
[48]	Other (carbon emission)	Unable to evaluate the actual carbon emission to indicate number in the market
[49]	Other (carbon, methane, nitrogen emission)	To fully determine the amount of methane and other nitrous gas effects on the environment
[50]	Other (tax exemptions)	To develop a model estimates the cost and surplus by employing tax exemptions

such as amount of crude oil to purchase, how much to produce, and other processing and distribution requirement. The solution utilized was known to be effective as compared to the other methods such as Expected Value of Perfect Information (EVPI).

Ref. [54] proposed an auxiliary Markov Chain model for uncertainty in lead time. The solution technique based on using the time Auxiliary Markov Chain was found not to be effective, and a method of using the general optimization algorithm is proposed. The paper focused on the search of the optimal values of the planned lead times for the Material Requirement Planning (MRP) method for the supply chain planning.

5.2. Simulation methods

Simulation methods are important tools for solving supply chain problems with uncertainties. There are different kinds of simulation: static, dynamic, discrete and continuous, deterministic and stochastic. This depends on the system state and case. In this work, Monte Carlo (MC) and Discrete event (DE) simulations are presented. Generally, the MC simulation is used to solve static problems. An example is the Scenario Generation (SG). The DE simulation can be used for solving problems in dynamic systems, such as queuing systems. For further reading on Monte Carlo, Scenario Generation and Queuing Systems, refer to [c–f].

5.2.1. Discrete event simulation methods

Discrete event simulation methods can be applied to many supply chain problems to solve uncertainties.

Ref. [55] used a simulation based optimization approach to solve a deterministic planning and scheduling model, which incorporate safety stock levels as a means of accommodating demand uncertainty. The simulation based optimization framework is developed for decision making with respect to project portfolio selection and project task scheduling. The computational framework, called the "Sim-Opt", combines deterministic mathematical programming for maximization of net present value.

A simulation methodology developed by [56], is based on analytical queuing networks, with nonlinear optimization, to design supply chain topologies and evaluate performance measures. The simulation approach is based on different network scenarios for the uncertain parameters. The results obtained from the network configurations demonstrated this technique as a useful tool to analyze congestion problems, and to evaluate the performance of the network topologies.

The paper by [57] uses a queuing network dynamic simulation to study the short product life cycle case shown by Tamagotchi. To simulate the supply chain dynamics, all the echelons are consisted of scenarios based on the Tamagotchi case, and are integrated into the dynamic model. The model has three components; market, retail and factory for the uncertainty analysis.

5.2.2. Monte Carlo simulation methods

Many supply chain stochastic problems have applied Monte Carlo simulation to solve uncertainties. A stochastic simulation based on dynamic system is used in modeling a network design consisting of plants, warehouse and possible customer based locations by [58]. A solution technique based on the Monte Carlo simulation and sampling techniques is used. A Markov Decision Process (MDP) based on Monte Carlo Sampling technique in providing a cost effective supply chain management is considered by [59]. The solution technique employed an algorithm that uses a decomposition approach for the scalability of the problem.

To solve a bi-criteria model, a hybridization of multi-objective particle swarm optimization and simulation optimization are considered by [60,61] respectively. The papers employed the Monte Carlo based approach for the mean and standard deviation of the uncertain parameters in each case. The solution found was known to be effective and insightful in solving a supply chain problem with demand uncertainties. Ref. [62] applied a scenario generation technique through a simulation approach applied based on discrete event simulation. The uncertainty is to make a decision for production based on fuzzy demand and unreliable supply. A solution technique based on solving the LP after simulation is used.

6. Sustainability concepts and models in biofuel supply chain

Sustainability means meeting today's energy needs for environmental stewardship, economic prosperity, and quality of life without compromising future generations' ability to meet these needs of energy for themselves [63]. As discussed by [64–66], assessing the true potential of sustainability will require the production, trade and final conversion of the biofuel. Sustainability concepts must be analyzed taking into consideration the issues of the environment and socio-economic policies [67,68,36,69].

6.1. Environmental concept

Environmental sustainability outlines policy visions that have been laid down to prevent the degradation of the agricultural forest, and decrease the GHG emission and other environmental issues [70]. The major issues of environmental sustainability are; (1) GHG emission, (2) water resources quality (3) soil degradation and loss of biodiversity.

Greenhouse gas is the atmospheric gas that absorbs and emits radiation. In biofuels, the amount of emission is lower as compared to gasoline. Biofuels burn cleaner than gasoline, resulting in fewer greenhouse gas emissions. Biofuels are fully biodegradable, in comparison with other fuel additives. Cellulosic ethanol has the potential to cut greenhouse gas emissions by up to 86% [71]. Ethanol is a safe, high-performance replacement for most fuel additives. The use of ethanol can increase emissions of some air pollutants, because fossil energy is used during the farming of biomass crops and during biofuel production. These emissions can be reduced by using renewable power and improved farming methods.

Clean, fresh water is essential to public health and environment. The impact of biofuels on water quality is due to the issue of intensified and expanded corn production on water quality. The increase in demand for energy crops will result in price rise in crops encouraging farmers to grow more feedstock based crops. Corn, soy, wheat and other profitable crops will be grown to increase crop yields. High corn prices will encourage farmers to expand total acreage of land under cultivation, therefore affecting lands set aside for erosion control and habitat protection [72].

Soil degradation and erosion is the washing away of the surface of land as a result of rain, wind and other man-made and natural phenomenon. In the absence of strict enforcement of best practices, these issues can increase. An analysis on ensuring yield gains is not achieved at the expense of environmental quality. Each of these actions might increase erosion and contaminated runoff into streams, rivers and oceans leading to soil erosion. A further increase in erosion could occur if high corn prices reduce the attractiveness of financial incentives offered to farmers. This will prevent putting erosion prevention plans in place as part of USDA's Conservation Security Program [72].

6.2. Economical concept

The economic issue of biofuel includes, but not limited to the following; (1) food versus fuel debate, (2) efficiency and energy balance, and (3) increasing biofuel budget programs [73,67,74].

Food versus fuel debate is attributed to many biofuel feedstocks like corn, sugarcane, and soybeans that are key sources of food being substituted for energy. Production of crops for bioenergy uses may displace food-related crops. This can increase the cost and decrease the availability of foodstuffs, including plant and animal-based foods [69]. This is the reason second, third and fourth generation biofuels feed stocks such as cellulosic grass, switchgrass, miscanthus and algae are being explored currently. These raw materials do not compete with food, and provide higher conversion rates, and cheap cost of cultivating.

Efficiency and energy balance is the goal to expend less energy by using energy efficient materials and means. Energy related raw materials and means are configured and changed to become more energy efficient, meaning they use less energy to make their product. Ref. [75] energy efficiency and renewable energy interrelationship is the twin pillars of sustainable energy policy. Greenhouse gases have also been connected with products that are less energy efficient.

Increasing biofuel budget programs can increase the economic activities of farmers. This is achieved in the area of feedstock cultivation, new land acquisition, varying land for different commodity harvesting, and increase revenue from investors [76]. Research expansion to include variety of feedstock for cellulosic technology will enable processors to take advantage of the flow of a variety of biomass feedstock. This will encourage water-friendly feedstock of perennial grasses and trees.

6.3. Social concept

This is to analyze the social issues of biofuel development, for example, the potential of technological innovation and how it enhances the society. Some of the issues of social sustainability concept include; (1) poverty reduction potential, (2) land and crop indirect impacts, and (3) effects on social resources, such as water utility systems.

The development of biofuels occurs in the rural areas where there are opportunities for agriculture. These areas are inhabited by the under privileged, and in some cases small-scale and subsistence farmers. Biofuel is argued to contribute to poverty alleviation through provision of energy by increasing the income and economic per capita [77]. Distribution of this wealth can create equity and improvement in the quality of life of communities that have biofuel developments. States like North Dakota can commit to promote biofuels mainly in response to societal development and poverty alleviation agenda. The achievement of this goal can be developed through a structured development program.

Land is central to the issue of biofuel production. In order to gain maximum benefit from biofuels, large tracks of land are required for biofuel crop production. Land and crop indirectly affect the land tenure system and the decision on the variety of feedstock to invest in. High corn prices encourage farmers to expand the total acreage of land under cultivation. This possibly leads into lands set aside for erosion control and habitat protection. Conventional management methods in differentiating these land uses according to physical criteria [78]. However, actual land uses, not only change according to physical factors, but change in demands from market opportunities, society and stakeholders' entitlement.

The production of liquid biofuels is rapidly increasing, mainly due to the establishment of large scale biofuel feedstock plantations. Provision of quality water, is therefore essential in this regard [79]. Clean, fresh water is essential to public health; therefore a reliable water utility system is essential. In the short term, the impact of biofuels on water system quality will be inadequacy and pollution of water. This might be due total land acquisition increasing raw material cultivation.

6.4. Modeling sustainability issues in supply chain

Modeling sustainability issues is to integrate the interdependence of environmental, social, and economic concepts in the supply chain decision making. There is little literature that models the sustainability issues in biofuel supply chain. But some models have been found in general supply chain problems.

A Mixed Integer Linear Programming (MILP) model is developed by [80] for a multi period supply chain. The decision is to determine the optimal values of the quantities between sites and the CO_2 emission trading. The model is solved by using a direct methodology based on the simplex method.

Ref. [81] proposes a model which describes the physical relationships among different environmental activities and the natural water cycle, to evaluate the economic impact of water policy sustainability. An integrated material flow account approach is evaluated. This framework allows the analyst to consider both the effect of given policies on the water cycle and the constraint produced by the sustainability problem on the economic system.

Ref. [82] presents a conceptual model relating plant and soil biodiversity framework for future studies in soil degradation. A discussion of the economic benefits of soil biodiversity to society as part of a wider strategy of conserving and using agro based biodiversity. Further interrelation on how management options might be interfaced with farmers' knowledge in taking management decisions.

Ref. [83] develops an economic model that examines the tradeoffs in resources and consumption due to crop-based biofuel development. A proposed solution framework based on a utility function representing consumption of a number of goods is discussed. To assist with the sector development that maximizes welfare gains, a suggestion of a number of key indicators used in constructing a typology is given. Final demonstration on the developing of renewable energy sources with maximum impact on human welfare and development.

Ref. [84] proposed a goal programming (GP) model to address efficiency and energy balance in a multi-objective supply chain sustainability. The analytic hierarchy process (AHP), a multi-objective decision making method, is used to evaluate the priorities of goals and weights of the deviation variables. The application of this approach is illustrated through a case study on sustainable supply chain optimization and scheduling of a petrochemical complex. The results obtained show that this approach is offers flexibility in the supply chain realizations for decision making with sustainability.

In applying sustainability indicators as objectives for a mixed-integer optimization model [85] developed a balanced petrochemical network to reduce entire network cost of a typical petrochemical industry. A simple Monte Carlo simulation is used to accommodate variations in prices and demand. The results indicate a useful balance in cost reduction, by incorporating rice uncertainties in price, comparing with economic effects in all three types of sustainability.

Ref. [86] applied correlation and descriptive analysis in the incorporation of poverty reduction as part of sustainability in a developing economy. The paper shows that reliable energy-based indicators of poverty can be created through one-dimensional indicator and the explanatory power of energy poverty indicators. A final conclusion is made basis that energy indicators are not restricted to environmental and economic issues, but is also relevant for social issues.

An inexact-stochastic quadratic programming is developed by [87] with recourse method to tackle nonlinearities of a marginal utility system. The objective is to evaluate the benefits and costs analysis for the water system uncertainties. The developed method is applied to a case study of planning resources management and developing regional ecological sustainability.

7. Conclusions and future research

Renewable energy is an important part of today's energy sources. Biofuel is one of the renewable energy types that serve as an alternative and additive to fossil fuel for transportation purposes. In this work, a provision of the general overview of the background and structure of the biofuel supply chain is considered. Also, a literature of the decision making process, and the uncertainties in the supply chain are provided. Subsequently, methodologies that have been applied in other supply chain to handle uncertainties are provided. Finally, sustainability concepts are discussed, and suggestions made for the incorporation of sustainability issues in biofuel supply chain.

Due to the uncertainties in the biofuel supply chain, it is important to incorporate these uncertainties in the decision making process. Further solution methods should be explored in considering these uncertainties. Methodologies such as analytical, simulation and other hybrid methods can be utilized in solving biofuel supply chain problems with uncertainties. Some hedging strategies need to be considered to hedge the risks in biofuel supply chain. The risks include risks from feedstock supply and price, oil price shocks, and other forms of risks within and outside the biofuel supply chain. Applying operational and financial hedging tools will be a potential research direction.

Uncertainty in the biofuel supply chain can be modeled by using either scenario or distribution based approaches. In the scenario based approach, the uncertainty can be described by a set of discrete scenarios, capturing future uncertainty. Each scenario can be associated with a probability level representing the decision maker's expectation of the occurrence of a particular scenario. The distribution based scheme can be used when a set of discrete scenarios cannot be identified, and only a continuous range of potential figures can be predicted. Incorporating these processes in modeling biofuel supply chain uncertainties might be useful in obtaining optimal decision.

Literature in modeling sustainability issues in biofuel supply chain has not been given the needed attention. However, sustainability issues impact the health of the biofuel supply chain. The effect of underestimating sustainability can lead to planning decisions that are either risky or will not take advantage of the opportunities that higher levels of sustainability provide. Therefore, models that seek to combine economic, social and environmental sustainability concepts should be a future direction of research in biofuel supply chain.

The most important reason for making biofuel an option for renewable energy is to increase energy security, sustainability, as well as to deliver competitive lower cost products to the end-user market. In order to achieve a higher level of optimization, the biofuel supply chain management should apply models that incorporate uncertainty and sustainability concepts. For instance, to explore the optimal decisions in the production quantity of biofuel, we should incorporate demand and price uncertainties as well as sustainability issues like carbon trading.

Finally, an optimal supply chain should be designed for the new generation of biofuel in order to commercialize the products. Uncertainties and sustainability issues should be considered and incorporated when modeling the new generation biofuel supply chain management problems.

Appendix A. Further reading

Reading on the Monte Carlo, Queuing Theory and others are referred in [c–f]

[c] Metropolis N. The beginning of the Monte Carlo method. Los Alamos Science (1987 Special Issue dedicated to Stanislaw Ulam) 125–30. http://library.lanl.gov/la-pubs/00326866.pdf.

[d] Mitra S. A white paper on scenario generation for stochastic programming; July, 2006.

[f] Jones DW. Empirical comparison of priority queue and event set implementations, Communications of the ACM, 29; April, 1986, p. 300–11.

References

[1] EPA. Energy policy act; 2009, http://www.seco.cpa.state.tx.us/energy-sources/biomass/epact2005.php.
[2] Zolin MB. Biomass energy: new opportunity for agriculture and marginal areas, Working Papers; 2008, dse.unive.it.
[3] Demirbas A. Political economic and environmental impacts of biofuel: a review. Applied Energy 2009;86:S108–17.
[4] Redman G. Assessment of on-farm AD in the UK, The Andersons Centre, National Non-Food Crops Centre, 09.06.08 [retrieved 11.05.09].
[5] UNEP, United Nation Energy Program; 2009, http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=512&ArticleID=5616&l=en.
[6] IEA, International Energy Agency; 2009, http://www.iea.org/stats/electricitydata.asp.
[7] Oliver RI, King DA. Quo Vadis biofuel. Energy & Environmental Science 2009;2:343, doi:10.1039/b822951.
[8] Naik SN, Vaibhav V, Prasant GKR, Ajay KD. Production of first and second generation biofuel: a comprehensive review. Renewable and Sustainable Energy Reviews 2009;14:578–97.
[9] Chakrabortty A. Secret report: biofuel caused food crisis, The Guardian; July, 2008 UK.
[10] Chopra S, Meindl C. Supply chain management: strategy, planning, and operations. second ed. New York: Prentice Hall; 2003.
[11] Iakovou E, Karagiannidis A, Vlachos D, Toka A, Malamakis A. Waste biomass-to-energy supply chain management: a critical synthesis. Waste Management 2010;30:1860–70.
[12] Eksioglu DS, Acharya A, Leightly LE, Arora S. Analysing the design and management of biomass-to-biorefineries supply chain. Computers and Industrial Engineering 2009:1342–52.
[13] Gronalt M, Rauch P. Designing a regional forest fuel supply network. Biomass and Biofuel 2007;31:393–402.
[14] Hamelinck CN, Suurs RA, Faaij APC. International biofuel transport costs and energy balance. Biomass and Biofuel 2005;29:114–34.
[15] Atchison JE, Hettenhaus JR. Innovative methods for corn stover collecting, handling, storing and transporting, Technical report, NREL/SR-510-33893. National Renewable Energy Laboratory; 2004.
[16] Huang Y, Chen CW, Fan Y. Multistage optimization of the supply chains of biofuel. Journal of Transportation Research 2010;46:820–30.
[17] Gnansounou E. Production and use of lignocellulosic bioethanol in Europe: current situation and perspectives. Bioresource Technology 2010;101:4842–50.
[18] Kang S, Önal H, Ouyang Y, Scheffran J, Tursun ÜD. Optimizing the biofuel infrastructure: transportation networks and biorefinery locations in Illinois. Natural Resource Management and Policy 2010;33:151–73.
[19] Leduc S, Dotzauer E, Obersteiner M. Biofuel from gasification: a facility location problem. International Journal of Energy Research 2008:1080–91.
[20] Brennan L, Owende P. Biofuels from microalgae — a review of technologies for production, processing, and extractions of biofuels and co-products. Renewable and Sustainable Energy Reviews 2010;14:557–77.
[21] Lamers P, Hamelinck C, Junginger M, Faaij A. International bioenergy trade — a review of past developments in the liquid biofuel market. Renewable and Sustainable Energy Reviews 2011;15:2655–76.
[22] Grisso RD, Cundiff JF, Ravula PP. Cotton logistics as a model for a biomass transportation system. Biomass and Bioenergy 2008;32:314–25.
[23] Kumar A, Sokhansan S, Turhollow AF. Development and implementation of integrated biomass supply analysis and logistics model (IBSAL). Biomass and Bioenergy 2006;30:838–47.
[24] Gabbar HM. Engineering design of green hybrid energy production and supply chains. Environmental Modelling & Software 2009;24:423–35.
[25] Hamelinck CN, Faaij APC. Future prospects for production of biofuel and hydrogen from biomass. Journal of Power Sources 2005;111:1–22.
[26] Assimacopoulos D, Voivontas D, Koukios EG. Assessment of biomass potential for power production: a GIS based method. Biomass and Biofuel 2001;20:101–12.
[27] Skoulou V, Zabaniotou A. Investigation of agricultural and animal wastes in Greece and their allocation to potential application for energy production. Renewable and Sustainable Energy Reviews 2007;11:1698–719.
[28] Papadopoulos DP, Katsigiannis PA. Biomass energy surveying and techno-economic assessment of suitable CHP system installations. Biomass and Biofuel 2002;22:105–24.
[29] Gan J. Supply of biomass, biofuel, and carbon mitigation: method and application. Energy Policy 2007;35:6003–9.

[30] Helms RD, El-Halwagi EM. The effect of greenhouse gas policy on the design and scheduling of biodiesel plants with multiple feedstocks. Clean Technologies and Environmental Policy, Springer; 2004.
[31] Helms RD, El-Halwagi EM. Optimal scheduling and operation of biodiesel plants with multiple feedstocks. International Journal of Process Systems 2009;1:1–28.
[32] Meyer S. US biofuel analysis under uncertainties and volatility in the biofuel industry: FAPRI stochastic modeling, biofuel, food and feed tradeoffs; 2007. p. 12–13.
[33] Markandya A, Pemberton M. Energy security, energy modeling and uncertainties. Energy Policy 2010;38:1609–13.
[34] Dal-Mas M, Giarola S, Zamboni A, Bezzo F. Capacity planning and financial optimization of the biofuel supply chain under price uncertainties. In: 20th European symposium on computer aided process engineering. 2010. ESCAPE20.
[35] Cadre E, Orset C. Irreversible investment, uncertainties, and ambiguity: the case of bioenergy sector, Cahiers de recherché working papers 2010/03.
[36] Treleven M, Schweikhart SB. A risk/benefit analysis of sourcing strategies: single vs. multiple sourcing. Journal of Operations Management 1988;7:93–114.
[37] Yano CA, Lee HL. Lot sizing with random yields: a review. Operations Research 1995;43:311–34.
[38] Caeser WK, Riese J, Seitz T. Betting on biofuel. The Mckinsey Quarterly 2007;2:54–63.
[39] Nagel J. Biomass in energy supply, especially in the state of Brandenburg, Germany. Ecological Engineering 2000;16:S103–10.
[40] Ravindranath N, Manuvie HR, Fargione J, Canadell P, Berndes G, Woods J, et al. GHG implications of land use and land conversion to biofuel crops, biofuel report; 2009, p. 1–18.
[41] Berndes G, Hoogwijk M, van den Broek R. The contribution of biomass in the future global energy supply: a review of 17 studies. Biomass and Bioenergy 2003;25:1–28.
[42] Dautzenberg K, Hanf J. Biofuel chain development in Germany: organisation, opportunities, and challenges. Energy Policy 2008;36:485–9.
[43] Schmidt J, Leduc S, Dotzauer E, Kindermann G, Schmid E. Using Monte Carlo simulation to account for uncertainties in the spatial explicit modeling of biomass fired combined heat and power potentials in Austria; 2009.
[44] Eksioglu DS, Acharya A, Leightly LE, Arora S. Analysing the design and management of biomass-to-biorefineries supply chain. Computers and Industrial Engineering 2009:1342–52.
[45] Cruz Jr JB, Tan RR, Culaba AB. A dynamic input–output model for nascent bioenergy supply chains. Applied Energy 2009;86:S86–94.
[46] Ochoa S, Wozna G, Repke JW. Plantwide optimizing control of a continuous biofuel production process. Journal of Process Control 2010;20:983–98.
[47] Cadre E, Orset C. Irreversible investment, uncertainties, and ambiguity: the case of bioenergy sector. Cahiers de recherché working papers; 2010/03.
[48] Hammond GP, Kallu S, McManus MC. Development of biofuel for the UK automotive market. Applied Energy 2008;85:506–15.
[49] Mortimer ND, Elsayed MA. North east biofuel supply chain carbon intensity assessment. North Energy 2006:1–59.
[50] Rozakis S, Sourie JC. Micro-economic modeling of biofuel system in France to determine tax exemption policy under uncertainties. Energy Policy 2005;33:171–82.
[51] Kim J, Realff MJ, Lee JH. Optimal design and global sensitivity analysis of biomass supply chain networks for biofuels under uncertainty. Computers and Chemical Engineering 2011;35:1738–51.
[52] Sodhi MS, Tang CS. Modeling supply chain planning under demand uncertainty using stochastic programming: a survey motivated by asset-liability management. International Journal of Production Economics 2009;121:728–38.
[53] Lababidi HMS, El-Wakeel MA, Alatiqi IM, Al-Enzi AF. Optimizing the supply chain of petrochemical products under uncertain operational and economical conditions. Working paper, jdt - nt.ntnu.no.
[54] Al-Othmani WEB, Lababidi HMS, Alatiqi IM, Al-Enzi AF. Supply chain optimization of petroleum organization under uncertainty in market demands and prices. European Journal of Operations Research 2008;189:822–40.
[55] Jung JY, Blau G, Pekny JF, Reklaitis GV, Eversdyk D. A simulation based optimization approach to supply chain management under demand uncertainty. Computers and Chemical Engineering 2004;28:2087–106.
[56] Kerbache L, Smith JM. Queuing networks and the topological design of supply chain systems. International Journal of Production Economics 2004;91:251–72.
[57] Higuchia T, Troutt MD. Dynamic simulation of the supply chain for a short life cycle product—lessons from the Tamagotchi case. Computers & Operations Research 2004;31:1097–114.
[58] Hung WY, Kucherenko S, Samsatli NJ, Shah N. A flexible and generic approach to dynamic modelling of supply chains. Journal of Operations Research Society 2004;55:801–13.
[59] Subrahmanyam S, Peknyt JF, Reklaitis GV. Design of batch chemical-plants under market uncertainty. Industrial Engineering and Chemical Resource 1994;33:2688–701.
[60] Jung JY, Blau G, Pekny JF, Reklaitis GV, Eversdy D. A simulation based optimization approach to supply chain management under demand uncertainty. Computers and Chemical Engineering 2004;28:2087–106.
[61] Mahnam M, Reza M, Vahid Y, Seyed FD, Hejazi R. Supply chain modeling in uncertain environment with bi-objective approach. Computers & Industrial Engineering 2009;56:1535–44.
[62] Miranda PA, Garrido RA. Incorporating inventory control decisions into a strategic distribution network design model with stochastic demand. Transportation Research Part E: Logistic Transportation Review 2004;40:183–207.
[63] Sabri EH, Beamon BM. A multi-objective approach to simultaneous strategic and operational planning in supply chain design. Omega International Journal of Management Science 2000;28:581–98.
[64] Ayuso AA, Escudero LF, Ortuno AGMT, Perez G. An approach for strategic supply chain planning under uncertainty based on stochastic 0-1 programming. Journal of Global Optimization 2003;26(1):97–124.
[65] Levis AA, Papageorgiou LG. A hierarchical solution approach for multi-site capacity planning under uncertainty in the pharmaceutical industry. Computing and Chemical Engineering 2004;28:707–25.
[66] Altiok T, Ranjan R. Multistage, pull-type production inventory systems. Institute of Industries Engineering Transactions 1995;27:190–200.
[67] Amiguna B, Kaviti MJ, Stafford W. Biofuels and sustainability in Africa. Renewable and Sustainable Energy Reviews 2010;15:1360–72.
[68] RFS, Renewable Fuel Standard, http://www.renewableenergyworld.com.
[69] Duku MH, Gu S, Hagan EB. A comprehensive review of biomass resources and biofuel potential in Ghana. Renewable and Sustainable Energy Reviews 2010;15:404–15.
[70] Tan RR, Aviso KB, Barilea IU, Culaba AB, Cruz Jr JB. A fuzzy multi-regional input–output optimization model for biomass production and trade under resource and footprint constraints. Applied Energy 2011;90:154–60.
[71] Biofuels & greenhouse gas emissions: myths versus facts; March, 2011, http://www.energy.gov/.
[72] Wood Institute for the Environment, Stamford University, The impacts of large-scale biofuel use on water resources.
[73] Inderwildi OR, King DA. Quo Vadis biofuels. Energy & Environmental Science 2009;2:343, doi:10.1039/b822951c.
[74] Karagiannidis A, Wittmaier M, Langer S, Bilitewski B, Malamakis A. Thermal processing of waste organic substrates: developing and applying an integrated framework for feasibility assessment in developing countries. Renewable and Sustainable Energy Reviews 2009;13:2156–62.
[75] Green Collar Operations, http://www.greencollaroperations.com/weatherization-austin-tx.html [retrieved 16.07.10].
[76] Demirbas A. Political, economic and environmental impacts of biofuel: a review. Applied Energy 2009;86:S108–17.
[77] Bell DR, Silalertruksa T, Gheewala SH, Kamens R. The net cost of biofuels in Thailand—an economic analysis. Energy Policy 2011;39:834–43.
[78] Peskett L, Slater R, Stevens C, Dufey A. Biofuels, agriculture and poverty reduction; 2007, March. DFID, London, UK.
[79] Bass S, Hawthorne W, Hughes C. Forests, biodiversity and livelihoods: linking policy and practice; 1998. Issues paper for DFID, London, UK.
[80] Paksoy T. Optimizing a supply chain network with emission trading factor. Scientific Research and Essays 2010;5(17):2535–46.
[81] Bertz R, Gunnthorsdottir A. Modeling emissions markets experimentally: the impact of price uncertainty. In: 18th world IMACS/MODSIM congress. 2009., http://mssanz.org.au/modsim09.
[82] Van Dam JEG, Klerk-Engels B, Struik PC, Rabbinge R. Securing renewable resource supplies for changing market demands in a bio-based economy. Industrial Crops and Products 2005;21:129–44.
[83] Zhou Z, Cheng S, Hua B. Supply chain optimization of continuous process industries with sustainability considerations. Computers and Chemical Engineering 2000;24:1151–8.
[84] Al-Sharrah G, Elkamel A, Almanssoor A. Sustainability indicators for decision-making and optimisation in the process industry: the case of the petrochemical industry. Chemical Engineering Science 2010;65:1452–61.
[85] Rentizelas A, Tolis A, Tatsiopoulos I. Biomass district energy trigeneration systems: emissions reduction and financial impact. Water Air Soil Pollution Focus 2008;9:139–50.
[86] Todorov VI, Manirova D. Models for sustainability. In: 18th world IMACS/MODSIM congress. 2009., http://mssanz.org.au/modsim09.
[87] Hutchins MJ, Sutherland JW. An exploration of measures of social sustainability and their application to supply chain decisions. Journal of Cleaner Production 2008;16:1688–98.